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# Present Status of Biological Control of Mite Pests in Taiwan

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## 摘　　要

**羅幹成** (1986) **臺灣害蟎生物防治之現況** 植保會刊 28：31～39 (臺灣省農業試驗所)

臺灣現有記錄之葉蟎類超過 50 種，但其中以在柑桔之柑桔葉蟎 (*Panonychus citri* (McGregor)) 和柑桔銹蟎 (*Phyllocoptruta oleivora* Ashmead)，溫帶果樹之二點葉蟎 (*Tetranychus urticae* Koch) 和歐洲葉蟎 (*Panonychus ulmi* Koch)，茶樹、草莓及桑樹上神澤葉蟎 (*Tetranychus kanzawai* Kishida) 及草莓上的二點葉蟎最爲重要。而葉蟎之天敵也有30種之多，其中14種屬捕食性昆蟲，另 16種則屬捕食性蟎類，其中以羅氏小黑瓢蟲 (*Stethorus loi* Sasaji)，小黑隱翅蟲 (*Oligota oviformis* (Casey))，西方瘦蠅 (*Arthrocnodax occidentalis Felt.*)，長毛捕植蟎 (*Amblyseius longispinosus* (Evans))，溫氏捕植蟎 (*A. womersleyi* Schicha)，卵形捕植蟎 (*A. ovalis* (Evans)) 及大形捕植蟎 (*A. herbicolus* (Chant)) 等 7 種最爲重要。

自從新型合成殺蟲劑之廣爲施用以來，由於葉蟎天敵大量遭受毒殺，因而使柑桔葉蟎猖獗發生。另一種柑桔銹蟎則對桔果嚴重危害，近年來發現一種寄生銹蟎之眞菌普遍在柑桔園內出現，曾以其菌絲之懸浮液噴施於田間柑桔，以測知其對銹蟎之致病性及防治效果，結果令人滿意。

在桑園內常見有 5 種捕植蟎與神澤葉蟎相伴發生，經比較測定獲知溫氏捕植蟎之分布模式與神澤葉蟎之棲群分布相配合，故溫氏捕植蟎被認爲是神澤葉蟎之最佳生物防治之天敵。進一步大量將此捕植蟎釋放於桑園，對神澤葉蟎具有滿意之防治效果。

神澤葉蟎和二點葉蟎亦爲害草莓，大量釋放長毛捕植蟎經 4 星期後對神澤葉蟎可具 85%之防治效果，但對二點葉蟎則效果不彰。最近自夏威夷引進加州捕植蟎 *Amblyseius californicus* (McGregor))，此蟎對本省氣候適應，在室內大量繁殖極爲容易，經田間釋放對二點葉蟎確有顯著防治功能，進一步田間大量釋放試驗正在進行中。

神澤葉蟎近年來又對本省茶樹構成嚴重危害，長毛捕植蟎雖亦在茶園中對神澤葉蟎可予有效控制，但由於對其他害蟲必須施用多種殺蟲劑，故長毛捕植蟎在茶園中出現密度極低，近年來在不同地區及作物上調查長毛捕植蟎，並以 10種茶園常用藥劑予以測試結果，發現本省具有 3 種抗藥性之長毛捕植蟎之品系。目前正以此抗藥性長毛捕植蟎大量繁殖供茶園釋放之用，試驗正在進行中。

二點葉蟎及歐洲葉蟎爲二種入侵本省之害蟎，而本省缺乏有效之天敵可予壓抑，又此二葉蟎之抗藥性又高，藥劑防治極爲困難，故近來又引進加州捕植蟎及法拉斯捕植蟎

(*Amblyseius fallacis* (Garman))，對此二葉蟎均屬強有力之天敵，大量繁殖及釋放正在進行中。

(關鍵字：生物防治、柑桔葉蟎、柑桔銹蟎、歐洲葉蟎、神澤葉蟎、二點葉蟎、溫帶果樹、桑樹、茶、草莓。)

## ABSTRACT

There are more than fifty species of spider mites have been recorded in Taiwan. The following species are considered the major pests on their host plants, i. e. citrus red spider mite, *Panonychus citri* (McGregor), citrus rust mite, *Phyllocoptruta oleivora* Ashmead on citrus; two-spotted spider mite, *Tetranychus urticae* (Koch) on deciduous fruit trees and strawberry; european red spider mite, *P. ulmi* (Koch) on deciduous fruit trees; kanzawa spider mite, *T. kanzawai* Kishida on tea, strawberry and mulberry. Thirty species of native predators were recorded, including 14 species predatory insects and 16 species of predatory mites. *Stethorus loi* Sasaji, *Oligota oviformis* (Casey), *Arthrocnodax occidentalis* Felt., *Amblyseius longispinosus* (Evans), *A. womersleyi* Schicha, *A. ovalis* (Evans), and *A. herbicolus* (Chant) were identified as more important ones.

The infestation of citrus red mite is becoming rather severe in citrus orchards since its beneficial predators are sacrified by the extensive and frequent use of insecticides. A serious damage to citrus fruit caused by citrus rust mite. Recently, it was found commonly infested by an entomogenous fungus, *Hirsutella thompsonii* Fish. The fungus mycelia were used for field spray in order to evaluate its pathogenicity and effectiveness in the rust mite control. Encouraged results were obtained.

Five species of *Amblyseius* mites associated with kanzawa spider mite in the mulberry groves. Field distribution pattern of *A. womersleyi* did match kanzawa spider mite population distribution. *A. womersleyi* was evaluated as the best biocontrol agent for kanzawa spider mite population. Mass releases of this predators to the mulberry groves, bringing about satisfactory control.

Kanzawa spider mite and two spotted spider mite also attack strawberry in Taiwan. Mass releases of *A. longispinosus* resulted in an overall 85% reduction in the kanzawa spider mite population after 4 weeks initial releases. But for two-spotted spider mits, it gave poor control results. Recently, a new phytoseiid, *A. californicus* (McGregor) has been introduced from Hawaii, this predatory mite is relatively easy to mass-rear. Plots in which predators were primarily mass released had established and lower populations of *T. urticae*. Further field colonization is now in progress.

Kanzawa spider mite also can be serious pest in Taiwan tea plants. In some fields the predatory mite, *A. longispinosus* is an effective predator of

the kanzawa spider mite. Pesticides used to control the tea insect pests can disrupt this biological control. 10 insecticides were used to select the predators which were collected from different locations and plants, and selected this predators for resistance to carbamates, organophosphates and pyrethoids in the laboratory and obtained dimethoate, dimethoate-carbaryl and carbaryl resistant strains. Mass release and field colonization is now in progress.

Two-spotted spider mite and european red spider mite are newly invaded mite pests. Because they also readily develop resistance to pesticides, effective biological control is especially desirable. Recently, *Amblyseius fallacis* (Gaman) and *A. californicus* (McGrogor) were imported from Michigan and Hawaii, respectively, as potential biological control agent of both spider mites on deciduous fruit trees. Mass-rear is now in progress.

(Key words: Biological control, Citrus red spider mite, citrus rust mite, european red spider mite, kanzawa spider mite, two-spotted spider mite, deciduous fruit trees, mulberry, tea, strawberry.)

## INTRODUCTION

Before the 'DDT era' mite pests and their natural enemies on crops had received attention from only a few people. However, shortly after DDT and other synthetic organic insecticides had become widely used, reports of outbreaks of tetranychid mites on various crops began to appear frequently in entomological literature. These outbreaks of mites in the early 1960's to 1970's created an impetus for studying plant-feeding mites and their predators. Research since that time can be classified into five different phases, which have overlapped chronologically: 1). Faunistic surveys, 2). Biological and ecological studies, 3). Field and insectary studies, 4). Implementation of biological control of mites on crops, and 5). Introduction and establishment of phytoseiids. Classical biological control of mites in Taiwan has not been conducted until quite recently, only about five years ago. The present paper is concerned with the biological control of mite pests on citrus, deciduous fruit trees, mulberry, tea, and strawberry.

## BIOLOGICAL CONTROL PROGRAMS

### I. Citrus

Four species of false spider mites: *Brevipalpus californicus* (Banks), *B. lewisi* McGregor, *B. obovatus* Donnadieu, and *B. phoenicis* (Geijskes); six species of spider mites, *Eotetranychus asiaticus* Ehara, *E. sexmaculatus* (Riley), *Eutetranychus orientalis* (Klein), *Panonychus citri* (McGregor), *Schizotetranychus baltazarae* Rimando and *Tetranychus kanzawai* Kishida, and one species of rust mite, *Phyllocoptruta oleivora* Ashmead, have been recorded as citrus pests. Recently, the citrus red mite, *P. citri*, and citrus rust mite, *P. oleivora*, are the most injurious citrus pests.

The infestation by the citrus red mite, is becoming rather severe in many citrus orchards because its predators are destroyed by the extensive and frequent

use of insecticides. Because of the increasing seriousness of the mite problem and the difficulties in attaining satisfactory chemical control, the search for effective natural enemies is being procelded assiduously.

According to Lo's survey, five insect predators of the citrus red mite have been recorded, viz., *Stethorus loi* Sasaji (Coccinellidae, Coleoptera), *Oligota oviformis* (Casey) (Staphylinidae, Coleoptera), *Chrysopa boninensis* Okamoto (Chrysopidae, Neuroptera), *Scolothrips sexmaculatus* Perg. (Thripidae, Thysanoptera), and *Leptothrips* sp. (Phloeothripidae, Thysanoptera); 3 species of phytoseiids, *Amblyseius herbicolus* (Chant), *A. okinawanus* Ehara, and *A. longispinosus* (Evans); and a species of entomogenous fungus, *Hirsutella thompsonii* Fisher.

Among the predaceous natural enemies, *Stethorus* was the most effective species in the areas of high prey population densities. *Oligota* was inferior due to its high mortality which occurred in the pupal stage in the soil. Prey consumption by *Chrysopa* was very high, however, when honeydew on citrus foliage is not sufficient to provide food necessary for reproduction its population decreased. *Scolothrips* and *Leptothrips* were rarely found on citrus. *Amblyseius herbicolus* is a dominant predator, but mass production of this phytoseiid is difficult.

Recently, the citrus rust mite was found to be commonly infected by an entomogenous fungus, *H. thompsonii*. The mycelia of this fungus were tested in field sprays to evaluate its pathogenicity and effectiveness against the citrus rust mite. One week after application the percentage of infection of citrus rust mite on treated trees averaged from 29.6 to 51.5% in 3 concentrations of mycelia suspension, whereas the untreated trees averaged 4.4%. However, the percentage of the diseased mites on treated trees did not increase after 2 to 4 weeks after application.

In the meantime a commercial product of the same fungus was obtained from Dr. McCoy, University of Florida. The effectiveness of this commercial strain of *H. thompsonii* will be compared with our local strain.

**II Deciduous fruit trees**

Five tenuipalpids; vie., *Brevipalpus californicus* (Banks), *B. lewisi* McGregor, *B. obovatus* Donnadieu, *B. phoenicis* (Geijskes), and *Tenuipalpus anoplus* Baker and Pritchard; seven tetranychids, *Eutetranychus orientalis* (Klein), *Oligonychus biharensis* (Hirst), *Panonychus citri* (McGregor), *P. ulmi* (Koch), *Tetranychus kanzawai* Kishida, *T. urticae* (Koch), and *T. viennensis* Zacher; and three eriophyids, *Aculus cornutus* (Banks), *A. schlechtendali* (Nal.), and *Epitrimerus pyri* (Nal.) are recorded as mite pests of deciduous fruit trees in Taiwan. The two-spotted spider mite, *T. urticae*, and the european spider mite, *P. ulmi* are considered to be the key mite pests.

Unfortunately, *T. urticae*, and *P. ulmi* are newly established pests in Taiwan (established not more than 6 years ago). These species exhibit a very high level of resistance to the most acaricides. Three phytoseiids have been introduced for control these spider mites. *Typhlodromus occidentalis* Nesbitt was imported from Dr. Hoy, University of California, Berkeley, but it was not possible to mass produce it in our insectary. *Amblyseius*

*californicus* (McGregor) was sent to Taiwan by Dr. Lai, State of Hawaii, Department of Agriculture. It is very easy to mass produce it in the insectary where it exhibited a very high reproductive capacity. It became readily established on the strawberry and tea plantations, but failed in the deciduous fruit tree orchards of the high mountain areas. *Amblyseius fallacis* (Garman) was recieved from Dr. Whalon, Michigan State University. This species along with others including *longispinosus* (Evans), and *californicus* (McGregor) belongs to the same group as *fallacis*. This group generally has a high reproductive capacity and hence warrant further studies for use in biological control. Field colonization is now in progress.

**III. Mulberry**

Seven species of mite pests on mulberry were recorded: one species of tenuipalpid, *Brevipalpus obovatus* Donnadieu, five species of tetranychid, *Panonychus citri* (McGregor), *Tetranychus cucurbitae* Rahman & Punjab, *T. kanzawai* Kishida, *T. piercei* McGregor, and *T. truncatus* Ehara; and one species of tarsonemid, *Polyphagotarsonemus latus* Banks. Among these, *T. kanzawai* is the key mite pest. Seasonal population densities and field distribution patterns of the five species of *Amblyseius* mites associated with *T. kanzawai* were studied in the mulberry groves by Shih (1983). Population density of *Amblyseius ovalis* (Evans) was the highest, but its distribution pattern did not match with that of its prey, *T. kanzawai*. The predation by *A. ovalis* did not have a significant effect on spider mite population. The population of the predator, *A. womersleyi* Schicha, increased in synchrony with that of *T. kanzawai* in the field and its field distribution patterns matched with those of the spider mite. Seasonal population densities and population distribution patterns of *A. herbicolus* (Chant), *A. okinawanus* Ehara, and *A. maai* Tseng and those of the spider mite population were studied. The results showed that the population densities and distribution patterns of these predators were not in synchrony with those of the spider mites and hence were not effective biological control agents. *A. womersleyi* was evaluated to be the best biocontrol agent for spider mite control among the five tested predators.

The cost of mass-rearing the predatory mite, *A. womersleyi* was estimated on the basis of producing 20 and 200 million predators per year. The cost of maintenance and quality control of the stock colony for the mass rearing of predators and their prey was added into the cost of mass-rearing the predators. The estimated cost was 0.0085 and 0.006 (NT$) per predator when 20 and 200 million predators, respectively, were reared. Mass releases of this predator at the rate of 100,000 predators per hectare in the mulberry groves are adequate to give satisfactory mite control.

**IV. Tea**

Four species of tenuipalpids: *Brevipalpus californicus* (Banks), *B. obovatus* Donnadeiu, *B. pollentillae* Baker & Tuttle, and *Tenuipalpus antipodus* Collyer; two species of tetranychids, *Oligonychus coffeae* (Nietner) and *Tetranychus kanzawai* Kishida; one tuckerellid, *Tuckerella pavoniformis* (Ewing); two eriophyids, *Acaphylla steinwedeni* Keifer,

and *Calacarus carinatus* Green; one tarsonimid, *Polyphagotarsonemus latus* Banks, were recorded to injure the leaves of tea. Recently, the most important mite pest is the kanzawa spider mite, *T. kanzawai.*

Several species of natural enemies of spider mites were found; *Stethorus loi* Sasaji, *Agistemus* sp., *Oligota oviformis* (Casey), *Scolothrips sexmaculatus* Perg., and *Amblyseius longispinosus* (Evans). *S. loi* is often an effective predator of spider mites on tea. *A. longispinosus* exploits prey populations at lower densities than does *S. loi* and it usually appears early in the season. However, *S. loi* can disperse rapidly to areas of high mite infestations which prevents severe damage in the hot-spot areas of a tea plantation. On the other hand, we often have observed that phytoseiids are unable to exert their maximum predation potential in fields where the stigmaeid, *Agistemus* sp., is concurrently present at comparable densities. Because the activities of *O. oviformis* and *S. sexmaculatus* are very sporadic they are not effective predators for spider mite control.

In general we can concluds that *A. longispinosus* is the most potentially effective predator considering consistency of control, and adaptation to variable weather and crops.

The kanzawa spider mite can be a serious pest of tea in Taiwan. In some fields the predatory mite, *A. longispinosus*, is an effective predator of this pest. Pesticides used to control the tea green leaf hopper, *Empoasca formosana* (Padi); leaf rollers, *Homoa coffearia* Nietner, *Adoxophyes privatana* Walker; tea bagworm, *Mahasena minuscuta* Butler; and tea tussock moth, *Euproctis pseudoconspersa* Strand can destroy *A. longispinosus.* On the other hand, carbaryl, dursban, carbofuran and the new pyrethroid permethrin can cause serious outbreaks of spider mites.

On other crops, *A. longispinosus* is often associated with the kanzawa spider mite and is an effective biological agent on fruit trees, vegetables, flowering crops, beans and strawberry. As indicated by its presence in a wide range of habitats, *A. longispinosus* is a highly adaptive mite that has been exposed to pesticides. If it develops resistance to one or more of pesticides, it would be a "genetic improvement" of a biological control agent.

A resistant and a susceptible strain of *A. longispinosus* were obtained from Chrysanthemum at Changhua and from Taro at Hsinchu respecively. The $LC_{50}$ values of dimethoate, carbaryl and malathion for the resistant strain were ca. 15-, 17-, and 38-fold higher, respectivly, than those for the susceptible strain. This resistant strain is now being mass-reared in the insectary and field colonizations are now in progress.

**V. Strawberry**

An ecological study of spider mites and their native predators was conducted in the strawberry fields at Tahu, Miaoli. The populations of prey and predatory were monitored at weekly intervals during 1977-81. Six spider mites, *Tetranychus kanzawai* Kishida, *T. urticae* (Koch), *T. cinnabarinus* Boud., *Panonychus citri* (McGregor), *Schizotetranychus* sp., and *Brevipalpus obovatus* Donnadieu were present. Among these species, *T. kanzawai* and *T. urticae* were the dominant pests.

From 1977 to 1980, *T. kanzawai* was the predominant species, but since 1981 the two-spotted spider mite had become the dominant one. Population of spider mites in those three years usually started to increase during January to February and reached peaks of 225, 444 and 502 per leaf in mid-April (1978-79), early April (1979-80), and late March (1980-81), respectively. The population then declined abruptly to less than 5 mites per leaf. Seven predators, *Oligota oviformis* (Casey), *Stethorus loi* Sasaji, *Arthrocnodax occidentalis* Felt, *Scolothrips sexmaculatus* Pergande, *Amblyseius* spp., *Cunaxa* sp. and Ascid mites were present in the strawberry fields. *Amblyseius* spp. and *O. oviformis* were the dominant predators. Their populations usually reached a peak of no more than 1 per leaf between early March to late April. From this it was concluded that the mite populations on strawberry declined abruptly primarily due to the high precipitation, high relative humidity and a fungal disease.

Biological control of the kanzawa spider mite on strawberry was investigated at Taichung during 1981. Mass releases of *A. longispinosus* were made when at the rate of 2/plant, 5/plant, 10/plant and 20/plant and control. There were five treatments with four replications. The mean number of spider mites in the different treatments were significantly lower than that of the control from Feb. 26 through Mar. 26. The number of mites in the high rate release plots (20/plant and 10/plant) was also significantly lower than that of the low rate release plots (5/plant and 2/plant). The predator populations reached a peak of 7.2 and 6.6/plant in the 20/plant and 10/plant release plots one Mar. 12, respectively. The population of the predators reached a peak of 3.5 per leaf in the 5/plant release plots on Mar. 9, and 3.7 per leaf in the 2/plant release plots on Mar. 26. These results indicate that the released predators did increase even though the prey population was reduced.

Biological control of the two-spotted spider mite on strawberry was investigated at Miaoli during 1981. Mass release of *A. longispinosus* was made at the rate of 10/plant. Poor control was obtained. Only in the field with low prey density (13 per leaf) was the predator able suppress the growth of the prey poulation.

The efficiency of a predator at different prey densities in a confined predator-prey system was determined by use of *A. longispinosus* as the predator and the kanzawa spider mite and the two-spotted spider mite as preys. The consumption of nymphs of the kanzawa spider mite per predator was high at high prey densities, but the consumption of nymphs of two-spotted spider mite per predator increased at low prey densities and then decreased at high prey densities. These results should not be interpreted as being due to restriction of the predator activity caused by high prey aggregation. Rather, they were due to prey preference because the two-spotted spider mite being a newly introduced species in Taiwan is not a preferred food of *A. longispinosus*. Results of feeding studies support this explanation.

For the control of the two-spotted spider mite on strawberry, we introduced the California phytoseiid, *Amblyseius californicus*, from Hawaii. This predator

is very easy to mass-rear in the insectary and can be used for either inundative or inoculative releases in Taiwan. Mass-rearing and field releases of this phytoseiid are now in progress.

## CONCLUSIONS

Although more than 50 species of phytoseiids and 20 species of insect predators of mite pests have been recorded in Taiwan, only a few are considered to be of value. Generally these few species are abundant on commercial crops. There have been few investigations on the complex of phytoseiid mites and insect predators to determine whether two or more species are more effective than one alone. However, in the meantime introduction of predators from other areas should be continued.

Finally, to increase the utilization of phytoseiids in biological control and pest management programs, additional staff in research, extension, and mass production is required. Educational and extension programs are just as important as research. The key to success is the devlopment of a crop protection system, which involves monitoring of populations, application technical knowledge, and critical decision making at the right time. Biological control programs against of mite pests in the future may be more economical, more effective, and safer than complete reliance on chemical control.

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